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Title: PDV spectrogram automated extractions

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# PDV Spectrogram automated extractions Kickoff meeting



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### Photon Doppler velocimetry (PDV) measures the velocity of a surface along a line of sight

18th APS-SCCM and 24th AIRAPT

IOP Publishing

Journal of Physics: Conference Series 500 (2014) 142008

doi:10.1088/1742-6596/500/14/142008

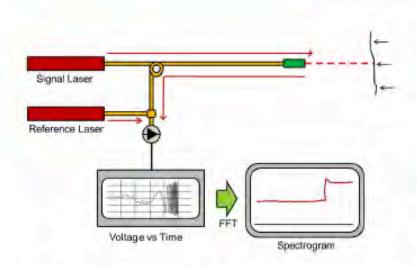


Figure 1. Diagram of a heterodyned PDV arrangement. In this arrangement, two separate lasers are beat together to form the velocimetry signal. The baseline of the signal is the frequency difference between the two lasers.

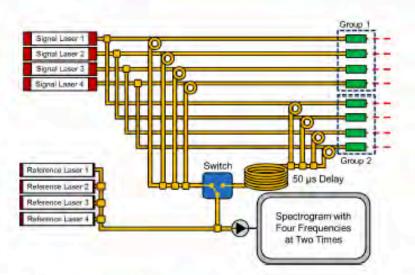
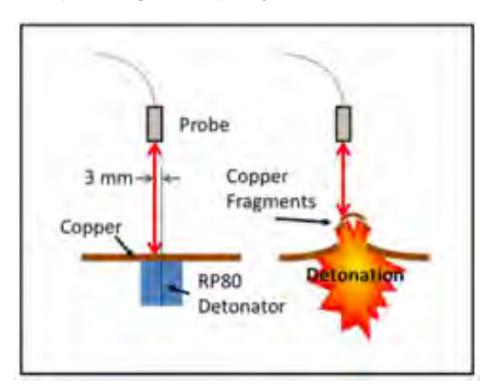


Figure 2. Simplified schematic of the 4 x 2 multiplexing employed in our systems. Combining eight lasers gives four frequency-multiplexed signals, while adding delayed channels and an optical switch allow two time-multiplexed signals.

#### (M)PDV is a workhorse diagnostic for LANL

LANL uses it on a variety of experiments, and are on track to generate thousands of spectrograms per year



Above: figure from Pat Harding describing Gen 3 evaluation shots at STL, May 2015. Right: figures from Journal of Physics: Conference series 500 (2014) 142008

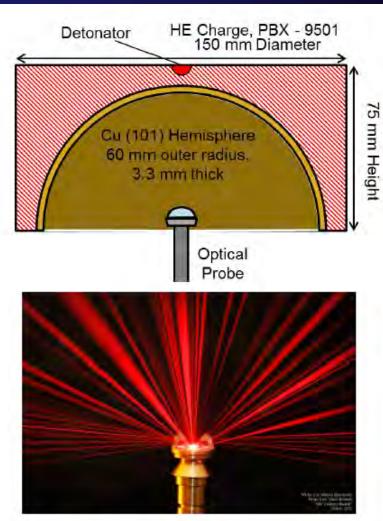
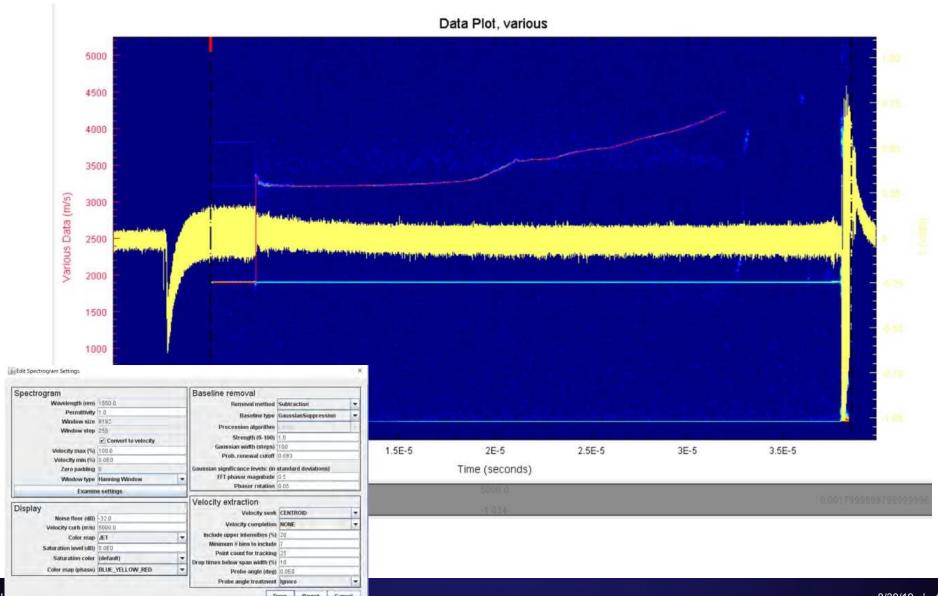
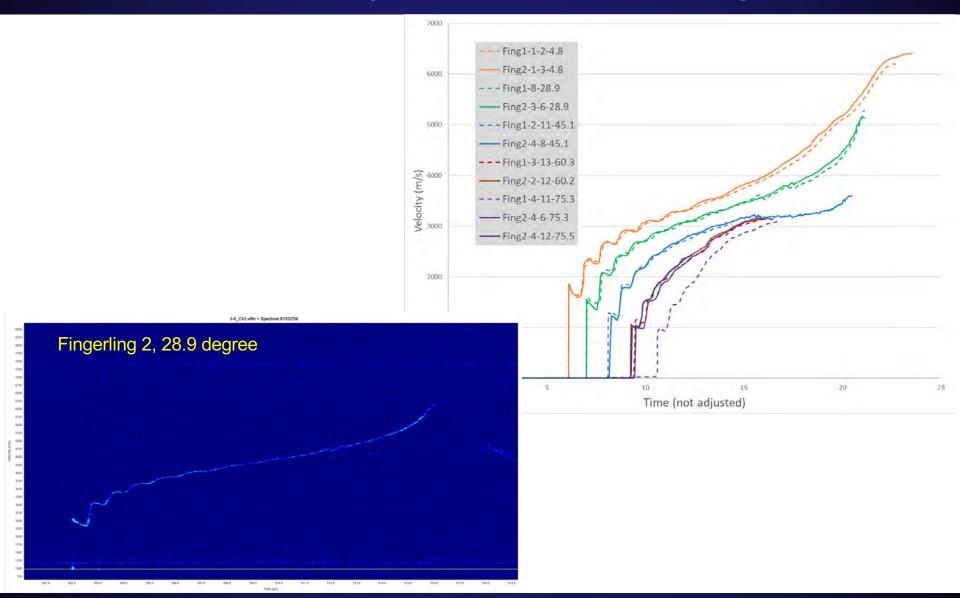


Figure 3. Image of the 120 channel optical probe used in the experiment. Photo by Brian Cox and Vince Romero, NStec, 2012.

#### PDV data are taken as a time series that is then Fourier transformed into a spectrogram



## In order to facilitate comparisons with models, we need to extract the velocity trace from the spectrogram

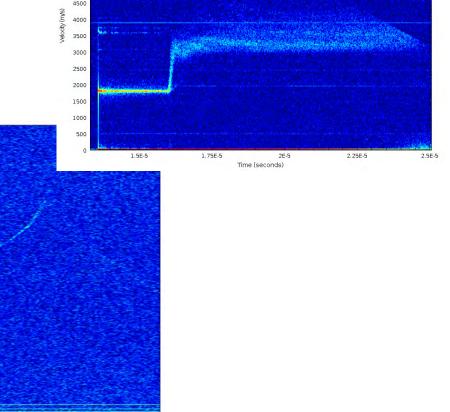


#### Right now our velocity traces are extracted by hand

6000

- Operator draws a "region of interest" around a trace in a spectrogram using a GUI tool
- The peak velocity is extracted from this region of interest
- We do not have a method for extracting velocity ranges

1-8 > Spectrum:8192/256



1 > Spectrum: 1024/128

#### Extracting the traces by hand presents a few problems

- By-hand extraction doesn't scale well in human time
- The extractions may be operator/extractor dependent (currently there's a single person who does most of LANL's extractions)
  - This could introduce a bias into our comparisons with models or using these data for calibration
- The extractions we have now don't have defensible uncertainties associated with them
  - This is a problem for model comparisons! Are we over or underfitting our data?

### LANL needs a (mostly) automated method for extracting velocity traces from spectrograms

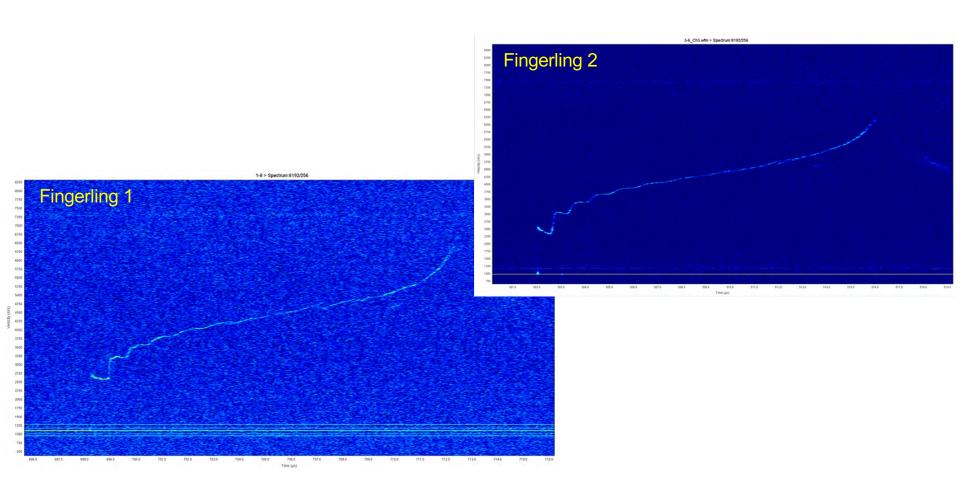
#### What it has to do:

- Read in the time-series data (this will be a specific, static data format unique to LANL)
- Perform a FFT on the data to get a spectrogram (we will give you our FFT method but you may use a different FFT or set of FFTs)
- Extract the velocity (or velocities) as a function of time
- Find the uncertainty on the velocity or velocities as a function of time
- Output the extracted velocity or velocities as well as uncertainty as a function of time
- Needs to give answers that do not depend on an operator
- Should be as automated as possible but can rely on human intervention
  - The intermediate steps should be auditable by the user

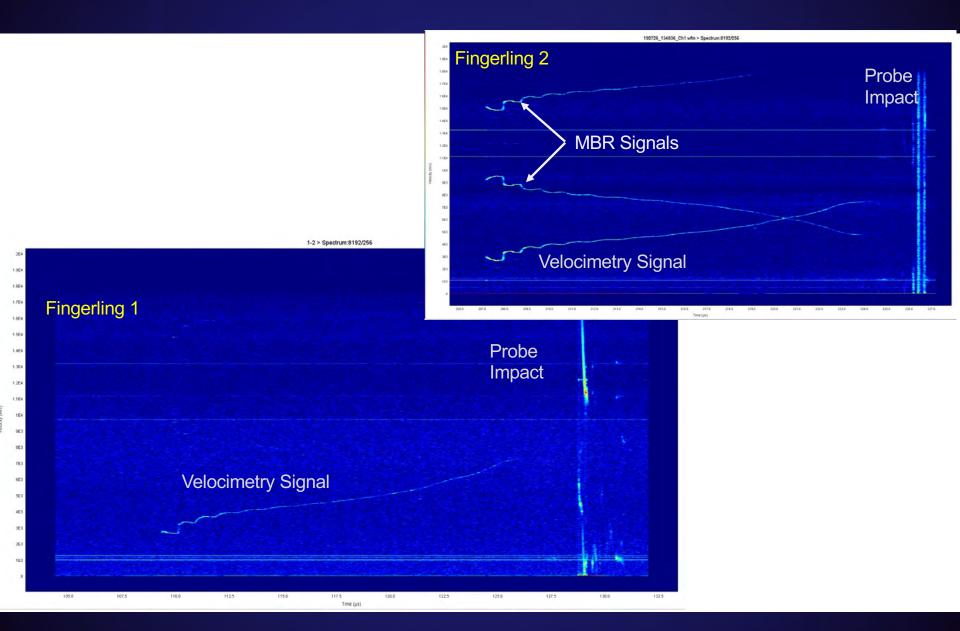
This is the hard part!

# Non-multiplexed PDV spectrograms are relatively simple

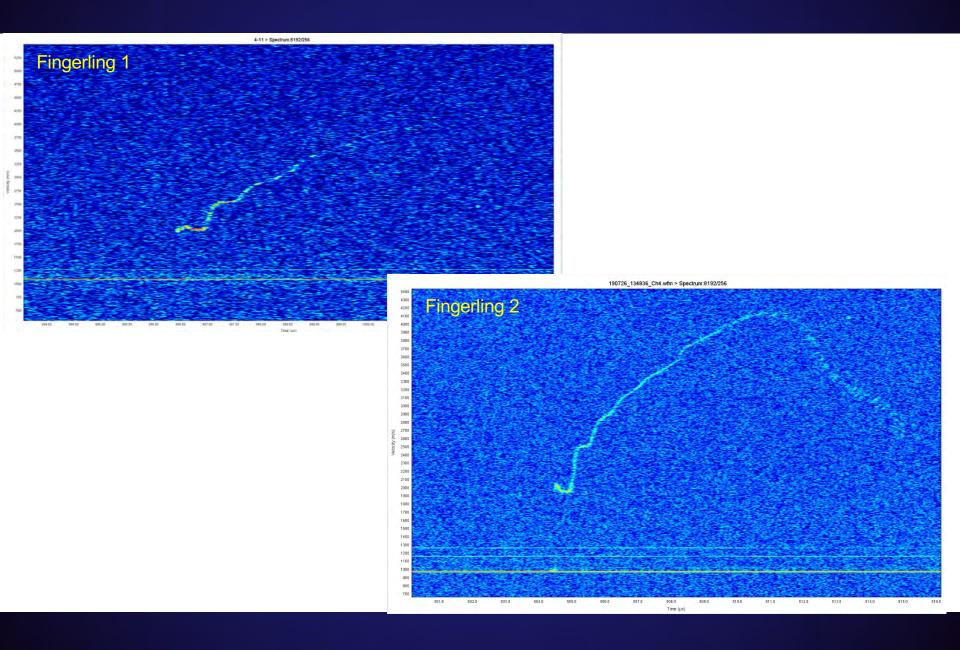
• Spectrogram Comparison Polar Angle 28.9



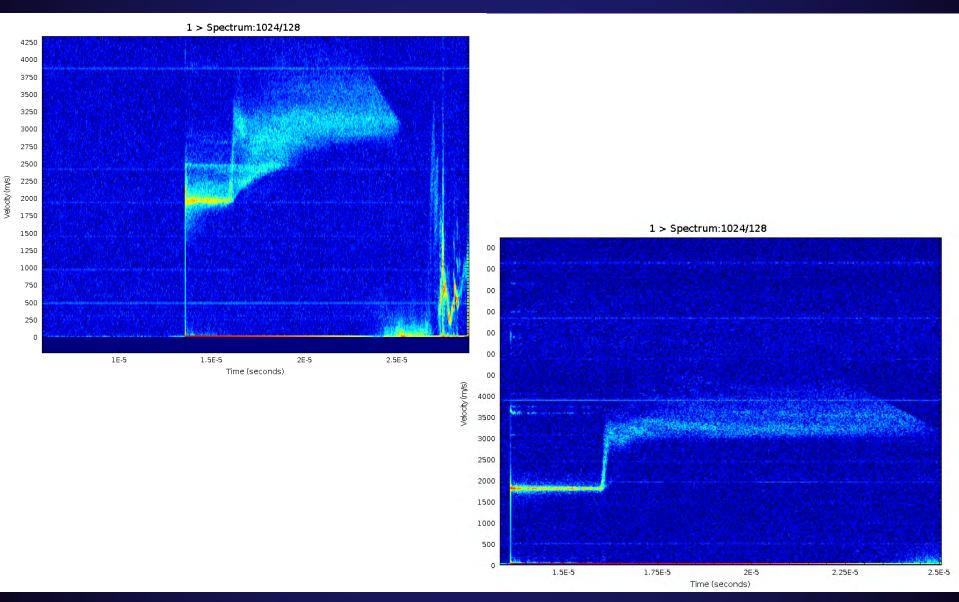
#### **Spectrogram Comparison Polar Angle 4.8**



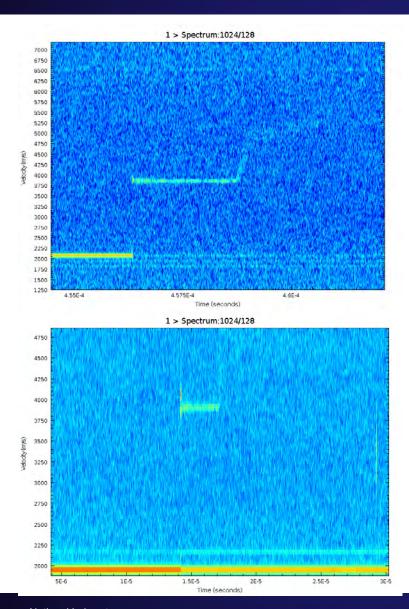
#### **Spectrogram Comparison Polar Angle 75.3**

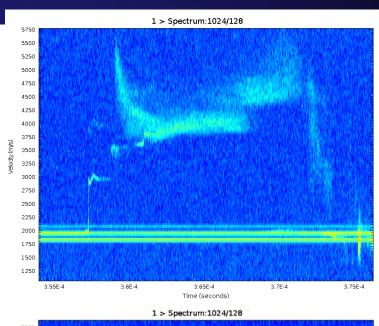


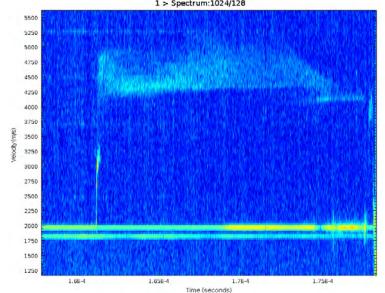
# The spectrograms become more complicated when multiple velocities are present



#### More examples of velocity distributions



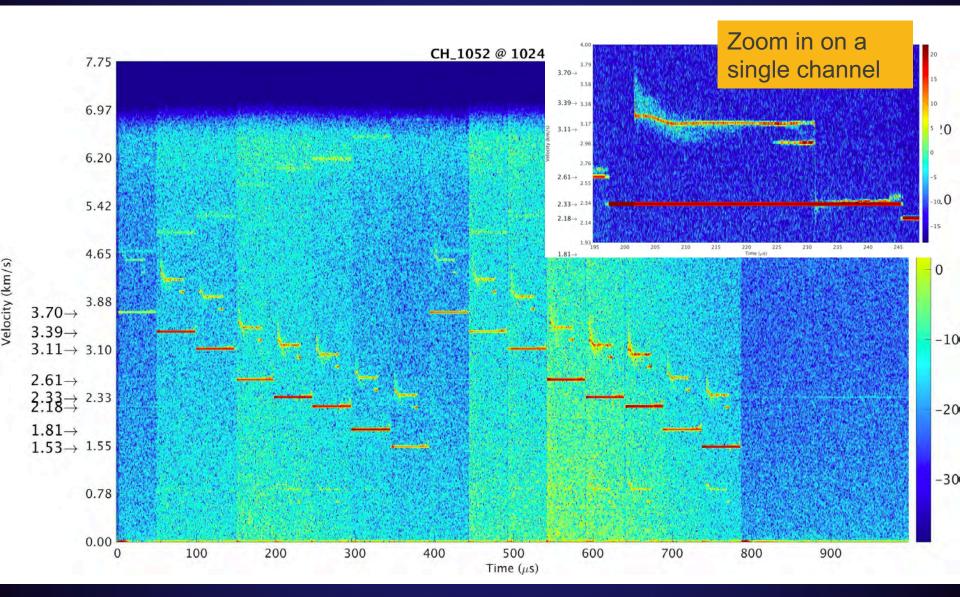




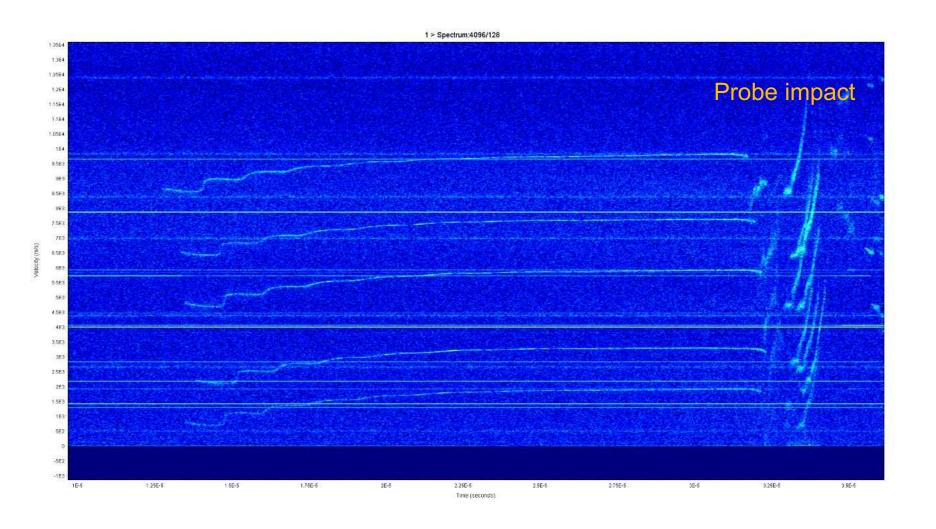
### Spectrograms from multiplexed systems are even more complicated

- PDV data can be multiplexed in frequency (you will see this referred to as Gen 1 or 2 MPDV) or time (Gen 3 MPDV)
- We do this because digitizing scopes are expensive
  - Multiplexing allows us to make more measurements per scope.

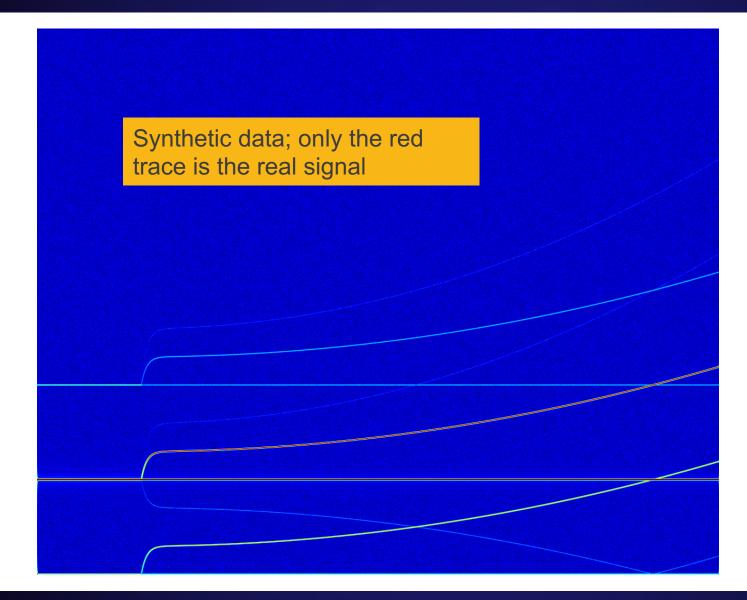
### Time multiplexed (Gen 3) spectrograms are a little less complicated then frequency multiplexed spectrograms



#### Frequency multiplexed (Gen I and 2) PDV spectrograms are more complicated than time multiplexed spectrograms



#### The laser heterodyning scheme can produce echoes



### The software will have to meet functional as well as non-functional requirements

- The software must meet these functional requirements:
  - Extract (multiple) velocities from:
    - non-multiplexed spectrograms
    - time-multiplexed spectrograms
    - frequency-multiplexed spectrograms
  - Provide velocity uncertainties based on signal-to-noise ratio as a function of time
  - Have a way to output multiple velocities or a range of velocities
    - Convey a velocity range when there is clearly a smooth distribution of velocities
    - Convey multiple velocities when there are discrete velocity traces
    - Stretch goal: convey relative signal strength as a function of velocity
    - These should be iterated with me
  - Resulting velocity traces and uncertainties cannot depend on person running the software
    - Software does not need to be fully automated
    - It should be as automated as possible, though
    - User intervention should be kept to a minimum

### The software will have to meet functional as well as non-functional requirements

- The software must meet these non-functional requirements:
  - Written in a commonly-used scientific programming language, preferably
     Python
    - LANL will consider other language choices
    - Open-source package dependencies are acceptable
    - Code will need to run on systems with no internet access
  - Follow good software construction practices:
    - Adhere to a commonly used style guide (for Python, PEP 8) for the language chosen
    - Choose readability over brevity—the people using and possibly modifying this code will not be computer scientists
    - Be written so as to be modifiable; allow for, e.g.,
      - Different output file formats
      - Different FFT methods
      - Different ways of measuring uncertainty
      - Different ways of representing multiple velocities or velocity ranges
      - Different methods for signal extraction
    - Each component should include tests that cover its capabilities.

#### Suggested path for tackling this problem

- First, write a reader for the time-series data
  - We will provide a .dig file, an ASCII version of this file, a spectrogram resulting from an FFT of the same file, and an extracted velocity from that spectrogram as a first step
- Produce a spectrogram that is the same as the ones LANL already uses by using the same FFT as LANL
  - At a later point in the process, it might be worth revisiting the FFT step to enhance extractions of quickly- or slowly-changing signals
- Start with simple spectrograms: either "vanilla" (non-multiplexed) or Gen 3 MPDV with single velocities
- As a next step, tackle something more difficult:
  - Traces with a velocity distribution rather than a single velocity
  - Frequency-multiplexed spectrograms
- LANL will provide an extensive set of time series data for use as inputs

## Distinguishing the velocity signal from other features may be the most challenging part of the problem

- It's even harder to distinguish the real signal if you don't know what's signal and what may be an artifact
- Please ask us questions early on!
- (Annotated) pictures may be a better way to ask questions than words
- Changing the colormap on your spectrograms may enable you to see more features:
  - Jet is a terrible colormap (but it is the default in the program used to make the images here)
  - Sciviscolor.org is an excellent resource for maps that can show more detail

## Please contact someone at LANL when you have a question!

- PDV diagnostic experts who can help with interpreting spectrograms:
  - Matt Briggs (<u>briggs@lanl.gov</u>)
  - Gregg Sullivan (gsullivan@lanl.gov, 505-665-5072)
  - Patrick Younk (<u>pwyounk@lanl.gov</u>, 505-667-0145)
  - Pat Harding (jparding@lanl.gov, 505-606-0594)
  - Steve Gilbertson (<u>steveg@lanl.gov</u>, 505-664-0081)
  - Jeremy Danielson (jeremyd@lanl.gov, 505-606-0816)
  - Lori Primas (lorip@lanl.gov, 505-665-4794)
- Many of the above spend a fair amount of time traveling for work, and have access to email but not necessarily a phone. Email is best.
   Email with images explaining your question is even better.